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VERIFICATION OF A TRANSLATION

Assistant Commissioner for Patents
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MAT-8033US PATENT

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[Claim 1]

A radio communication method in a radio network system in which radio communication apparatuses transmit beacons using beacon periods so that the beacons do not conflict with one another, comprising:

a detection step in which a radio communication apparatus detects whether in the beacon period there are empty beacon slots before the beacon slot which is the period for transmitting beacons of that radio communication apparatus;

a step in which, when such empty beacon slots are detected in the detection step, the radio communication apparatus starts count of a specified number of super frames after which the beacon slot of the radio communication apparatus will be moved to one of the empty beacon slots;

a step in which the radio communication apparatus adds to a beacon moving status information for notifying the other radio communication apparatuses of the beacon slot movement processing state of the radio communication apparatus and also adds to the beacon beacon period occupancy information that consists of moving status information received from the other radio communication apparatuses, identifiers for specifying the radio communication apparatuses sending the moving status information, and a beacon slot position, which are linked, and transmits the beacon at the beacon slot of the radio communication apparatus; and

a step in which, after elapse of the specified number of super frames, the radio communication apparatus moves its beacon to the empty beacon slot and transmits the beacon, wherein

a state of use of the beacon slot is determined on the basis of the beacon moving status information and the beacon period occupancy information received by the radio communication apparatus.

[Claim 2]

A radio communication method according to claim 1, characterized in that the countdown of a specified number of super frames is not performed in a period in which beacons of the other radio communication apparatuses are present from the beacon slot of the radio communication apparatus in question until the end of the beacon period.

[Claim 3]

A radio communication method according to claim 1, characterized in that the specified number of super frames is at least one or more.

[Claim 4]

A radio communication method according to any one of claims 1 to 3, wherein, when the radio communication apparatus detects a change of beacon formation, that is, the arrangement of beacon slot positions of the radio communication apparatus, by checking the beacon and the beacon period occupancy information received by the radio communication apparatus, the radio communication apparatus performs detection of an empty beacon slot and movement processing for moving its beacon slot position to the empty slot.

[Claim 5]

A radio communication method according to claim 1, wherein the moving status information is a counter value of a movable counter that counts the specified number of super frames or a flag.

[Claim 6]

A radio communication method according to claim 4, characterized in that the radio communication apparatus secures at least the lowest two slots of the beacon formation as entry slots not performing data communication and, in the start transmission of a beacon with a radio communication apparatus joining the radio network system anew or again, transmits the beacon at a slot selected at random from among these entry slots, this becoming the beacon slot position of the radio communication apparatus.

[Claim 7]

A radio communication method according to claim 6, characterized by further comprising a step in which to a beacon, the radio communication apparatus adds beacon slot length information that indicates the length of the period down to the lowest slot of the beacon formation recognized by the radio communication apparatus, and in that

the radio communication apparatus receives beacons but does not perform data communication in a period calculated by adding the entry slot length to the maximum beacon slot length found from the beacon slot length information received from neighboring radio communication apparatuses.

[Claim 8]

A radio communication apparatus comprising:

a beacon receiving unit that receives a beacon and extracts a frame;

a frame judging unit that judges whether the extracted frame is a beacon frame and records in a recording unit beacon period occupancy information that consists of the reception slot position of the beacon, an

identifier specifying the radio communication apparatus that transmitted the beacon, and moving status information indicating whether the radio communication apparatus that transmitted the beacon is moving its beacon slot position, which are linked, and also records the beacon period occupancy information included in the beacon frame;

a beacon slot position control unit that sets, when empty beacon slots before the beacon slot of the radio communication apparatus are detected in a beacon period by checking all the beacon period occupancy information, the counter value in a movable counter of the specified number of super frames until the beacon slot of the radio communication apparatus is moved to the empty beacon slot;

a beacon transmission command unit that detects its own slot position in the beacon period that had been determined by the beacon slot position control unit, and orders transmission of a beacon; and

a frame forming unit that forms, in response to the instruction from the beacon transmission command unit, a beacon frame including the beacon period occupancy information generated from the received beacon, moving status information of the radio communication apparatus, and beacon slot length information indicating the total length of beacon slots calculated from the beacon received by the radio communication apparatus, wherein

the beacon slot position control unit commands change of the beacon slot position of the radio communication apparatus to the beacon transmission command unit in response to a notice of completion of countdown from the movable counter.

[Claim 9]

A radio communication apparatus according to claim 8, characterized in that the movable counter does not perform the count of the specified number of super frames in a period in which beacons of other radio communication apparatuses are present from the beacon slot of the radio communication apparatus in question until the end of the beacon period.

[Claim 10]

A radio communication apparatus according to claim 9, characterized in that the specified number of super frames is at least one or more.

[Claim 11]

A radio communication apparatus according to claim 8, wherein, when the beacon slot position control unit detects a change of beacon formation, that is, the arrangement of beacon slot positions of the radio communication apparatuses, by checking the received beacon and the beacon period occupancy information, the beacon position control unit performs detection of an empty beacon slot and movement processing for moving its beacon slot position to the empty beacon slot.

[Claim 12]

A radio communication apparatus according to claim 8, wherein the moving status information is a counter value of a movable counter that counts a specified number of super frames or a flag.

[Claim 13]

A radio communication apparatus according to claim 8, characterized in that the frame forming unit secures at least the two lowest

slots of the beacon formation as entry slots not performing data communication, and

in the start of transmission of a beacon by a radio communication apparatus joining the radio network system anew or again, the beacon slot position control unit instructs the beacon transmission command unit that a slot selected at random from among the entry slots is the beacon slot position of the radio communication apparatus.

[Claim 14]

A radio communication apparatus according to claim 8, characterized in that the frame judging unit receives a beacon during a period that is calculated by adding the length of the entry slots to the maximum beacon slot length found in the beacon slot length information received from neighboring radio communication apparatuses, and

the frame forming unit does not perform data communication during the period.

[Document Name] Specification

[Title of the Invention] Radio Communication Method and Radio Communication Apparatus

[Technical Field]

[0001]

The present invention relates to a radio communication method and a radio communication apparatus which are used when ad hoc communication in a radio communication network is performed.

[Background Art]

[0002]

Conventionally, as the radio communication method and the radio communication apparatus, for example, there are those described in Patent Document 1. Fig. 18 is a diagram showing the radio communication method described in Patent Document 1. With the radio communication method, radio communication apparatuses communicate with one another directly without a control station in the radio network.

[0003]

In Fig. 18, the radio communication apparatuses transmit management information including reception timing information of the start position of their reception, reception window information, and reception cycle information, at specified time intervals (M1 to M4). The other radio communication apparatuses, which can receive this management information, store reception timing, reception windows, and reception cycles in association with communication apparatus numbers of the corresponding radio communication apparatuses. At the time of

transmission of information, the other radio communication apparatuses find the reception start positions of the corresponding radio communication apparatuses from the reception timing, the reception windows, and the reception cycles of the radio communication apparatus to be communicated and transmit the information according to this timing.

[0004]

Note that during a management information exchange area (hereinafter referred to as "beacon period") (C1 to C5), all the radio communication apparatuses transmit management information during the beacon slots of the respective radio communication apparatuses and so exchange the management information.

[Patent Document 1] JP-A-2003-229869

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0005]

However, in the conventional method, since the beacon periods are at fixed times, a radio network system, in which it is unknown in advance how many beacons are transmitted, has problems described below. When radio communication apparatuses actually belonging to this radio network system have nodes far fewer than the number of nodes assumed in advance, there is long idle time in the beacon periods and communication efficiency is low.

[0006]

Since all the nodes continue to operate in a reception waiting state in the time of the beacon periods, a beacon period longer than necessary

consumes excess power. Thus, waste of power consumption increases.

[0007]

Moreover, when another radio network system which adopts the same radio communication format is present near the radio network system in question, the longer the beacon period is, the more likely it is that beacons or data communication of the two radio network systems conflict with one another.

[0008]

On the other hand, when the number of radio communication apparatuses joining this radio network system is larger than the number of nodes assumed in advance, empty slots of the beacons are insufficient and some of the radio communication apparatuses cannot participate in the radio network system.

[0009]

The present invention has been devised to solve the conventional problems described above, and an object thereof is to provide a radio communication method in which communication efficiency is high and waste of power consumption is slight even if the number of radio communication apparatuses participating in a radio network system fluctuates dynamically.

[Means for Solving the Problems]

[0010]

A radio communication method according to the invention is a radio communication method in a radio network system in which radio communication apparatuses transmit beacons using beacon periods so that

the beacons do not conflict with one another, comprising: a detection step in which a radio communication apparatus detects whether in the beacon period there are empty beacon slots before the beacon slot which is the period for transmitting beacons of that radio communication apparatus; a step in which, when such empty beacon slots are detected in the detection step, the radio communication apparatus starts count of a specified number of super frames after which the beacon slot of the radio communication apparatus will be moved to one of the empty beacon slots; a step in which the radio communication apparatus adds to a beacon moving status information for notifying the other radio communication apparatuses of the beacon slot movement processing state of the radio communication apparatus and also adds to the beacon beacon period occupancy information that consists of moving status information received from the other radio communication apparatuses, identifiers for specifying the radio communication apparatuses sending the moving status information, and a beacon slot position, which are linked, and transmits the beacon at the beacon slot of the radio communication apparatus; and a step in which, after elapse of the specified number of super frames, the radio communication apparatus moves its beacon to the empty beacon slot and transmits the beacon, wherein a state of use of the beacon slot is determined on the basis of the beacon moving status information and the beacon period occupancy information received by the radio communication apparatus.

[0011]

Consequently, the radio communication apparatus can change the length of the beacon period as required. Thus, it is possible to eliminate

disadvantages such as lowered communication efficiency and waste of electricity for consumption which occurs in a beacon period having a fixed length for a fixed number of nodes. Since the radio communication apparatus gives notice of the beacon slot moving status such as "start of count of the super frames", it is possible to make changes according to other beacon information transmitted in the same beacon period. Delay of one beacon period occurs in receiving beacon information sent from the next neighborhood radio communication apparatus, that is located in the 2 hops away. However, since the radio communication apparatus delays movement of its beacon slot position by time units of super frames, it is possible to accommodate this delay. Moreover, since the radio communication apparatus can also exchange beacon slot information with the next neighborhood radio communication apparatus, it is possible to prevent a beacon of the partner radio communication apparatus from conflicting with beacons of other radio communication apparatuses that are capable of communicating with the radio communication apparatus, when the beacon slot is moved.

[0012]

The radio communication method according to the invention is characterized in that the countdown of a specified number of super frames is not performed in a period in which beacons of the other radio communication apparatuses are present from the beacon slot of the radio communication apparatus in question until the end of the beacon period.

[0013]

Consequently, it is guaranteed that the radio communication

apparatus that has completed count of the super frames is the only radio communication apparatus that has changed a beacon slot in that neighborhood. Therefore, it is possible to perform a contraction operation on a beacon period without causing two radio communication apparatus moving to the same beacon slot position simultaneously.

[0014]

The radio communication method according to the invention is characterized in that the specified number of super frames is at least one or more.

[0015]

Consequently, although delay of one beacon period occurs until information on a beacon emitted by a next neighborhood radio communication apparatus arrives, since the radio communication apparatus delays movement of its beacon slot position by time units of super frames, it is possible to accommodate this delay.

[0016]

In the radio communication method according to the invention, when the radio communication apparatus detects a change of beacon formation, that is, the arrangement of beacon slot positions of the radio communication apparatus, by checking the beacon and the beacon period occupancy information received by the radio communication apparatus, the radio communication apparatus performs detection of an empty beacon slot and movement processing for moving its beacon slot position to the empty slot.

[0017]

Consequently, when the beacon formation is changing dynamically, it is possible to detect the change in an autonomous distributed manner and perform a contraction operation for a beacon period.

[0018]

The moving status information in the radio communication method according to the invention is a counter value of a movable counter that counts the specified number of super frames or a flag.

[0019]

If the flag is used, data transmitted and received among the radio communication apparatuses can be limited to minimum of one bit. This makes it possible to reduce communication time.

[0020]

The radio communication method according to the invention is characterized in that the radio communication apparatus secures at least the lowest two slots of the beacon formation consisting of the beacon slot position and the beacon period occupancy information of each radio communication apparatus as entry slots not performing data communication and, in the start transmission of a beacon with a radio communication apparatus joining the radio network system anew or again, transmits the beacon at a slot selected at random from among these entry slots, this becoming the beacon slot position of the radio communication apparatus.

[0021]

Consequently, when a radio communication apparatus joins a radio network system anew or when a radio communication apparatus, the

beacon slot position of which overlaps that of another radio communication apparatus due to geographical movement, joins the radio network system again by movement in the geographical position, it is possible to incorporate these radio communication apparatuses in beacon formation of the radio network system according to the same algorithm.

[0022]

The radio communication method according to the invention is characterized by further comprising a step in which to a beacon, the radio communication apparatus adds beacon slot length information that indicates the length of the period down to the lowest slot of the beacon formation recognized by the radio communication apparatus, and is characterized in that the radio communication apparatus receives beacons but does not perform data communication in a period calculated by adding the entry slot length to the maximum beacon slot length found from the beacon slot length information received from neighboring radio communication apparatuses.

[0023]

Consequently, even when a radio communication apparatus located near a neighboring radio communication apparatus starts transmitting a beacon at the entry slot detected there, the beacon can be received.

[0024]

The radio communication apparatus according to the invention is a radio communication apparatus comprising: a beacon receiving unit that receives a beacon and extracts a frame; a frame judging unit that judges whether the extracted frame is a beacon frame and records in a recording

unit beacon period occupancy information that consists of the reception slot position of the beacon, an identifier specifying the radio communication apparatus that transmitted the beacon, and moving status information indicating whether the radio communication apparatus that transmitted the beacon is moving its beacon slot position, which are linked, and also records the beacon period occupancy information included in the beacon frame; a beacon slot position control unit that sets, when empty beacon slots before the beacon slot of the radio communication apparatus are detected in a beacon period by checking all the beacon period occupancy information, the counter value in a movable counter of the specified number of super frames until the beacon slot of the radio communication apparatus is moved to the empty beacon slot; a beacon transmission command unit that detects its own slot position in the beacon period that had been determined by the beacon slot position control unit, and orders transmission of a beacon; and a frame forming unit that forms, in response to the instruction from the beacon transmission command unit, a beacon frame including the beacon period occupancy information generated from the received beacon, moving status information of the radio communication apparatus, and beacon slot length information indicating the total length of beacon slots calculated from the beacon received by the radio communication apparatus, wherein the beacon slot position control unit commands change of the beacon slot position of the radio communication apparatus to the beacon transmission command unit in response to a notice of completion of countdown from the movable counter.

[0025]

Consequently, it is possible to establish a radio communication apparatus that can perform a contraction operation in an autonomous distributed manner with exchange of minimum data without causing a situation in which two radio communication apparatus move to the same beacon slot position simultaneously and can communicate with radio communication apparatus, and also can form a radio network capable of performing communication with a radio communication apparatus that moves geographically to the neighborhood of other communication apparatuses all as nodes of the same group.

[0026]

The radio communication apparatus according to the invention is characterized in that the movable counter does not perform the count of the specified number of super frames in a period in which beacons of other radio communication apparatuses are present from the beacon slot of the radio communication apparatus in question until the end of the beacon period.

[0027]

Consequently, it is guaranteed that the radio communication apparatus that has completed count of the super frames is the only radio communication apparatus that has changed its beacon slot in that neighborhood. Therefore, it is possible to perform a contraction operation for a beacon period without causing a situation in which two radio communication apparatuses move to the same beacon slot position simultaneously.

[0028]

The radio communication apparatus according to the invention is

characterized in that the specified number of super frames is at least one or more.

[0029]

Delay of one beacon period occurs until information on a beacon emitted by the next neighborhood radio communication apparatus arrives. However, since the radio communication apparatus delays movement of its beacon slot position by time units of super frames, it is possible to accommodate this delay.

[0030]

In the radio communication apparatus according to the invention, when the beacon slot position control unit detects a change of beacon formation, that is, the arrangement of beacon slot positions of the radio communication apparatuses, by checking the received beacon and the beacon period occupancy information, the beacon position control unit performs detection of an empty beacon slot and movement processing for moving its beacon slot position to the empty beacon slot.

[0031]

Consequently, when the radio communication apparatus is under a situation in which the beacon formation is changed dynamically, it is possible to detect the change in an autonomous distributed manner and perform a contraction operation for a beacon period.

[0032]

In the radio communication apparatus according to the invention, the moving status information is a counter value of a movable counter that counts a specified number of super frames or a flag.

[0033]

Consequently, when the flag is used, transmission and reception data among the radio communication apparatuses can be limited to as little as one bit. This makes it possible to reduce communication time.

[0034]

The radio communication apparatus according to the invention is characterized in that the frame forming unit secures at least the two lowest slots of the beacon formation as entry slots not performing data communication, and in the start of transmission of a beacon by a radio communication apparatus joining the radio network system anew or again, the beacon slot position control unit instructs the beacon transmission command unit that a slot selected at random from among the entry slots is the beacon slot position of the radio communication apparatus.

[0035]

Consequently, when a radio communication apparatus joins a radio network system anew or when a radio communication apparatus, the beacon slot position of which overlaps those of the other radio communication apparatuses, joins the radio network system again by movement in the geographical position, it is possible to incorporate these radio communication apparatuses in a beacon formation of the radio network system according to the same algorithm.

[0036]

The radio communication apparatus according to the invention is characterized in that the frame judging unit receives a beacon during a period that is calculated by adding the length of the entry slots to the

maximum beacon slot length found in the beacon slot length information received from neighboring radio communication apparatuses, and the frame forming unit does not perform data communication during the period.

[0037]

Consequently, when a radio communication apparatus near the radio communication apparatuses located in the neighborhood which is joining the radio network system anew starts transmitting a beacon in the entry slot detected there, the beacon can be received by the other radio communication apparatuses.

[Effects of the Invention]

[0038]

As described above, according to the invention, it is possible to make a beacon period dynamically variable in length according to an autonomous distributed algorithm of the radio communication apparatus of the radio network system while minimizing conflict of beacons. Consequently, even if the number of radio communication apparatuses joining the radio network system fluctuates dynamically, it is possible to perform radio communication with high communication efficiency and less waste of consumed electricity.

[Best Mode for Carrying out the Invention]

[0039]

(First exemplary embodiment)

Fig. 1 is a diagram showing an arrangement of radio communication apparatuses forming a constitution of a radio network system carrying out the invention.

[0040]

In Fig. 1, the radio communication apparatuses A (101) to F (106) are capable of transmitting and receiving information to one another in the range of the communication areas 111 to 116. In other words, the radio communication apparatus A (101) can communicate with the radio communication apparatuses B (102), C (103), and D (104), the radio communication apparatuses B (102) can communicate with the radio communication apparatuses A (101) and D (104), the radio communication apparatus C (103) can communicate with A (101), D (104), and E (105), the radio communication apparatus D (104) can communicate with the radio communication apparatuses A (101), B (102), C (103), and F (106), and the radio communication apparatus E (105) can communicate with the radio communication apparatus C (103). Note that it is assumed that the radio communication apparatus G (107) does not belong to this radio network at first.

[0041]

Fig. 2 is a block diagram showing a constitution of these radio communication apparatuses.

[0042]

In Fig. 2, a radio L1 processing section 201 converts an analog signal received from an antenna 200 into a digital signal, generates a frame, converts the frame into an analog signal, and sends the analog signal from the antenna 200. This antenna 200 is a non-directional antenna, which emits a radio wave. This radio L1 processing section 201 corresponds to the beacon receiving section according to the invention.

[0043]

A frame judging section 202 judges whether a frame received by the radio L1 processing section 201 is a beacon frame or a data frame.

[0044]

Fig. 3 is a diagram showing a constitution of a beacon frame in this beacon period.

[0045]

In Fig. 3, in beacon sender information 301, a device ID of the radio communication apparatus transmitting this beacon is entered in a device ID 303, a counter value of a movable counter 206 described later is entered in a counter 304, and a beacon slot length grasped by the radio communication apparatus transmitting this beacon is entered in a beacon slot length 305. In beacon period occupancy information 302, a device ID 303 and a counter value 304, which are entered in the beacon sender information 301 in a beacon frame received by this radio communication apparatus in the immediately preceding super frame, are entered for each beacon in a device ID 306 and a counter 307, respectively, and the slot position of the received beacon is entered in a beacon slot position 308.

[0046]

A recording section 203 records occupancy states of the respective beacon slots included in the beacon sender information 301 and the beacon period occupancy information 302.

[0047]

Fig. 4 shows a format of a beacon slot state table recorded in the recording section 203.

[0048]

In Fig. 4, for each slot of a beacon, a slot number 401, the device ID 402 of a radio communication apparatus using the slot, a state of use 403 of slots, and the type register 404 of the slot are recorded. This state of use 403 of slots indicates whether a radio communication apparatus in the slot position plans to change the slot position. Values of the counters 304 and 307 are set in the state of use 403 of slots. The type of slot 404 indicates whether a beacon has been received in that slot (indicated by "Beacon" in the figure) or it is notified that the slot is occupied by beacon period occupancy information aa (indicated by "BPOIE" in the figure).

[0049]

The upper layer processing section 204 performs protocol processing for layers as high as or higher than a network layer.

[0050]

The beacon slot position control section 205 checks the beacon slot state table recorded in the recording section 203 and, if there are empty slots toward the beginning of the beacon period, performs processing for moving the slot position of the radio communication apparatus.

[0051]

The movable counter 206 counts super frames until movement of a beacon slot position of the radio communication apparatus is started. Usually, a value of 2 or more is set in the movable counter 206.

[0052]

The frame forming section 207 reads out necessary information from the recording section 203 and generates the beacon period occupancy

information. Further, the frame forming section 207 generates the beacon sender information 301 on the basis of information from the beacon position control section 205 and forms a beacon frame which includes management information. In addition, the frame forming section 207 receives data from the upper layer processing section 204 and forms a data frame.

[0053]

The beacon transmission command section 208 has a timer function for counting offset time and detects the radio communication apparatus' own slot position in the beacon period. Then, the beacon transmission command section 208 gives to the frame forming section 207 the timing for sending the formed frame to the radio L1 processing section 201 at the radio communication apparatus' own slot position in the beacon period started from the offset time.

[0054]

Operations and actions of the radio communication apparatus constituted as described above in the beacon period will be explained.

[0055]

Fig. 5 is a flow diagram showing a contraction operation for a beacon period performed by the radio communication apparatus according to this embodiment.

[0056]

First, the frame judging section 202 judges whether a frame received from another radio communication apparatus is a beacon frame (step S501). The frame judging section 202 records the device ID 303 and the counter value 304 included in the received beacon sender information

301 together with the device ID 402 and the state of slot use 403 of the device ID 402 entered in the beacon slot state table recorded in the recording section 203, at the slot number of the slot where the beacon was received. The frame judging section 202 sets beacon reception (Beacon) in the type register 404.

[0057]

In addition, the frame judging section 202 records values of the device ID 306 and the counter 307 together with the device ID 402 and the state of use 403 of slots described at the slot number corresponding to the beacon slot position 308 in the beacon period occupancy information 302 in the received beacon frame. The frame judging section 202 sets beacon period occupancy information (BPOIE) in the type register 404. Note that the recording in the beacon slot state table based on the beacon period occupancy information is performed for all of the beacon period occupancy information in this beacon frame (step S502).

[0058]

The beacon transmission command section 208 judges whether a slot position is the slot position for it to transmit its beacon (step S503) and, when it is the time for transmission, commands the frame forming section 207 to transmit the beacon frame (step S504).

[0059]

On the other hand, when it is not the time for transmission, the beacon transmission command section 208 judges whether the beacon period has elapsed (step S505) and, when the beacon period has not elapsed, returns to step S501. In this way, processing from step S501 to step S505

is repeated until the end of the beacon period, whereby slot states for all beacon frames received during the beacon period are recorded in the recording section 203.

[0060]

Note that this beacon period is a length calculated by adding three entry slots to the maximum beacon slot length 305 among all those received in the beacon sender information 301. This entry slot is a slot in which a radio communication apparatus, which has joined a network anew or has joined again, transmits a beacon. One of the three slots is selected arbitrarily as the entry slot. Consequently, it is possible to reduce a probability of conflict of first beacons at the time when plural radio communication apparatuses joining the network anew are present simultaneously.

[0061]

The radio communication apparatus according to the invention can also learn the slot state of a next neighborhood radio communication apparatus on the basis of the beacon period occupancy information 302.

[0062]

Next, when end of the beacon period has come, the beacon slot position control section 205 performs beacon slot position determination processing (step S506).

[0063]

Next, the frame judging section 202 waits until a super frame ends without receiving the beacon frame and returns to step S501 at a point when this cycle ends.

[0064]

Herein, the beacon slot position determination processing will be explained below.

[0065]

Fig. 6 is a flow diagram showing the beacon slot position determination processing of the radio communication apparatus.

[0066]

First, the beacon slot position control section 205 checks whether there is a change in a constitution of a beacon slot (hereinafter referred to as "beacon formation") compared to the last time, referring to the beacon slot state table recorded in the recording section 203 (step S601). When there is a change in the beacon formation, the beacon slot position control section 205 checks whether there is an empty slot in higher slots (slots closer to the top). When there is an empty slot, the beacon slot position control section 205 resets the counter to the maximum counter value (hereinafter described to as "FULL"; the maximum value is set to '3' in this embodiment) in the movable counter 206 (step S603). When there is no empty slot, the beacon slot position control section 205 sets the movable counter 206 to '0' (step S604).

[0067]

On the other hand, when there is no change in the position of the beacon slot compared to the last time, the bacon slot position control section 205 starts countdown for moving the slot position to the upper slot. That is, the beacon slot position control section 205 judges whether the movable counter 206 is '0'. When the movable counter 206 is '0', since there is no

empty slot in the higher slots, the beacon slot position control section 205 ends the processing.

[0068]

On the other hand, when the movable counter 206 is 1 or higher, the beacon slot position control section 205 checks in the beacon slot state table for the states of use 403 of slots lower than the beacon slot of the radio communication apparatus. When at least one of the states of use 403 is not '0', the beacon slot position control section 205 judges that another beacon slot position control section has started countdown for beacon slot position change and has preference. The beacon slot position control section 205 sets Full ('3' in this embodiment) in the movable counter 206 and holds the value (step S607). Since a radio communication apparatus in a lower beacon slot position has a priority of beacon slot position movement in this way, it is possible to reduce useless repetition of processing for movement to an empty slot.

[0069]

On the other hand, when all the lower slots are 0, since the radio communication apparatus in question has the highest priority for beacon slot position movement, the beacon slot position control section 205 counts down the movable counter 206 (step S608). Then, at a point when the counter value changes to 0 (step S609), in order to move the beacon slot position to the highest beacon slot that the radio communication apparatus has found to be empty, the beacon slot position control section 205 sets "time for beacon transmission" in the timer function of the beacon transmission command section 208.

[0070]

As described above, when there is an empty slot higher than the radio communication apparatus and there is no radio communication apparatus which plans to move and which is lower than the radio communication apparatus in question, the beacon slot position control section 205 moves the beacon slot position to the higher slot. Thus, it is possible to reduce a beacon period (hereinafter referred to as "contraction operation"). Consequently, the beacon period is adjusted to the minimum length required for the number of radio communication apparatuses belonging to the radio network system.

[0071]

The change of a slot position from a low slot to a high slot is performed three cycles of a super frame after the beacon slot position control section 205 decides to make the change. Thereafter, the beacon slot position control section 205 can grasp the beacon slot position of a radio communication apparatus in a position one hop apart from the radio communication apparatus in question on the basis of the beacon period occupancy information. Therefore, the beacon slot position control section 205 moves a beacon slot position of the radio communication apparatus to a high empty slot while avoiding the slot position. Thus, it is possible to avoid conflict of slot positions with the radio communication apparatus at positions one hop apart.

[0072]

Note that, although the reset value of the movable counter is set to 3 in this embodiment, the reset value is not limited to this and the same

advantage can be obtained in principle if the reset value is equal to or larger than 2. However, it is preferable to set the reset value to 3 or more taking into account the possibility that a radio communication apparatus determined not to be present in one within the period of one hop actually had moved in into one hop just during the process of searching for beacons.

[0073]

Moreover, since the beacon period determination processing explained in step S505 is performed, it is possible to detect a radio communication apparatus joining the radio network system anew in radio communication apparatus even if it has the positional relation as shown in Fig. 16.

[0074]

In Fig. 16, a radio communication apparatus A (1601) is capable of communicating with a radio communication apparatus B (1602) in a communication area 1611. The radio communication apparatus B (1602) is capable of communicating with the radio communication apparatus A (1601) and a radio communication apparatus C (1603) in a communication area 1612. The radio communication apparatus C (1603) is capable of communicating with the radio communication apparatus B (1602) and radio communication apparatuses D to M (1604) in a communication area 1613. Figs. 17 are diagrams showing using states of slots for each of the radio communication apparatuses.

[0075]

In Fig. 17(a), the radio communication apparatuses A to M transmit beacons at first to twelfth slots, respectively. Thus, the radio

communication apparatus A (1601) learns from the beacon sender information 301 and the beacon period information 302 from the radio communication apparatus B (1602), that second and third slots are used by beacons of the radio communication apparatus B and the radio communication apparatus C. The radio communication apparatus B learns, on the basis of the beacon sender information 301 and the beacon period information 302 of the radio communication apparatuses A and C, that the first and the third through the twelfth slots are used. At this point, the radio communication apparatus A adds nine extra slots in a beacon period on the basis of the beacon slot length data 305 from the radio communication apparatus B. Therefore, with the addition of the three slots to serve as entry slots, the radio communication apparatus A is in a beacon reception waiting state until the fifteenth slot. Therefore, when a radio communication apparatus X (1605) transmits a beacon for joining the radio network system at the fourteenth slot at the geographical point shown in Fig. 16 in the communication areas of the radio communication apparatuses A and C, the radio communication apparatus A can receive this beacon as shown in Fig. 17(b). If the radio communication apparatus A does not use the beacon slot length data 305 from the radio communication apparatus B for determination of a beacon period and does not add extra slots, the radio communication apparatus A recognizes the slots up to the sixth slot as one beacon period and does not receive beacons after the sixth slot. Therefore, the radio communication apparatus A cannot detect the radio communication apparatus X that has joined the radio network system anew.

[0076]

In this way, since the radio communication apparatus determines a beacon period using the beacon slot length data in the beacon sender information, it is possible to detect a beacon of a radio communication apparatus joining the radio network system anew.

[0077]

Operations at the time when a radio communication apparatus G (107) has joined the radio network system anew in the case in which the radio communication apparatuses A (101) to F (106) have the positional relation shown in Fig. 1 will be explained with reference to Figs. 7 to 10.

[0078]

Fig. 7(a) shows a state of use of respective beacon slots in the radio communication apparatuses A (101) to F (106) before the radio communication apparatus G (107) joins the radio network system.

[0079]

In Fig. 7(a), the radio communication apparatus A is transmitting a beacon As in the first beacon slot, the radio communication apparatus B is transmitting a beacon Bs in the second beacon slot, the radio communication apparatus C is transmitting a beacon Cs in the third beacon slot, the radio communication apparatus D is transmitting a beacon Ds in the fourth beacon slot, the radio communication apparatus E is transmitting a beacon Es in the second beacon slot, and the radio communication apparatus F is transmitting a beacon Fs in the fifth beacon slot. For example, the radio communication apparatus A indicates that the radio communication apparatus A is receiving beacons (Br to Dr) of the

radio communication apparatuses B to D, which are in the communication area of the radio communication apparatus A, in the second to the fourth slots. Moreover, the radio communication apparatus A knows from beacon period occupancy information Eb obtained from a beacon from the radio communication apparatus C that a beacon of the next neighborhood radio communication apparatus E is being transmitted at that second slot and knows from beacon period occupancy information Fb obtained from a beacon from the radio communication apparatus D that a beacon of the next neighborhood radio communication apparatus F is being transmitted in the fifth slot.

[0080]

The radio communication apparatus A secures the sixth through the eighth beacon slots as entry slots so that, even if a new radio communication apparatus transmits a beacon, the radio communication apparatus A can receive the beacon. An extra slot is provided in the radio communication apparatus E. The extra slot indicates that a time domain obtained by a sum of lengths of the entry slots from the maximum beacon slot length data 305 of the next neighborhood radio communication apparatus does not perform data communication and other processes and corresponds to a protection domain monitored in all times. Since the radio communication apparatus E has been notified in the beacon slot length information sent by the radio communication apparatus C that the maximum length is 7, one extra slot is provided in the radio communication apparatus E.

[0081]

Herein, the beacon period occupancy information will be additionally explained. In a radio network system in which a beacon period is shared in an autonomous distributed manner to transmit beacons, beacon slots have to be allocated such that two or more radio communication apparatuses do not communicate in the same beacon slot. However, this means that, in the case of radio communication apparatuses sharing the same beacon slot, it is impossible to judge which of the radio communication apparatuses should use the beacon slot. Therefore, it is necessary to have another radio communication apparatus judge which of the radio communication apparatuses has priority for the beacon slot. In other words, when beacon period occupancy information not including a device ID of a radio communication apparatus is received from a radio communication apparatus in the neighborhood in the beacon slot position for that radio communication apparatus, it is necessary to change that radio communication apparatus to another beacon slot since it appears that a problem has occurred in the beacon slot. Therefore, the radio communication apparatus stores, at the time of reception of a beacon, the slot position of the beacon together with the beacon sender information, and always transmits the beacon slot position as beacon period occupancy information at the time of transmission of a beacon. Consequently, the respective radio communication apparatuses can obtain information on a next neighborhood radio communication apparatuses that can receive a beacon.

[0082]

Fig. 7(b) shows a situation in which the radio communication

apparatus G has joined the radio network system.

[0083]

In Fig. 7(b), the radio communication apparatus G learns a slot state indicated by the radio communication apparatus G (717) from beacons received from the radio communication apparatuses A, B, and D in a communication area of the radio communication apparatus G. The radio communication apparatus G selects an arbitrary entry slot and transmits a beacon in order to join the radio network system anew. In this example, there are three entry slots. However, the entry slots are not limited to this. Note that, in this embodiment, the radio communication apparatus G enters in the eighth slot. At this point, since the radio communication apparatuses A, B, D, and G judge that the beacon formation is changed, the radio communication apparatuses A, B, D, and G search through the higher slots. However, the radio communication apparatuses other than the radio communication apparatus G cannot detect an empty slot among the high slots. Therefore, only the radio communication apparatus G transmits a beacon for which the counter 304 is set to '3'. The radio communication apparatuses A, B, and D receive this beacon and detect that the counter value 304 of the radio communication apparatus G is '3'.

[0084]

Fig. 7(c) is a diagram showing a state of use of the next beacon period.

[0085]

In Fig. 7(c), the beacon period occupancy information of the radio communication apparatus G is communicated to the radio communication

apparatuses C and F by the radio communication apparatuses A and D. Since the counter value at this point is that received by the radio communication apparatuses A and D in the previous cycle, the value of the counter is '3'.

[0086]

On the other hand, the radio communication apparatus G performs processing for movement of slot position, sets the counter value to '2' in the counter 304, and transmits a beacon. The radio communication apparatuses A, B, D receive the beacon with the counter 304 of the beacon sender information set to '2', from the radio communication apparatus G.

[0087]

The radio communication apparatus E enters the beacon sender information 301, which the radio communication apparatus C received directly, in the beacon period occupancy information 302 also received from the radio communication apparatus C. However, the radio communication apparatus E does not include information received as the beacon period occupancy information 302. Therefore, the radio communication apparatus E never learns the presence of the radio communication apparatus G. However, since the beacon slot length 305 of the beacon sender information received from the radio communication apparatus C is '8', the radio communication apparatus E sets the number of extra slots to '4'.

[0088]

Fig. 8(a) is a diagram showing a state of use of a beacon period at the time when the movable counter 206 of the radio communication

apparatus G changes to '0'.

[0089]

In Fig. 8(a), a beacon period of the radio communication apparatus G moves to a sixth beacon slot.

[0090]

As shown in Fig. 8(b), in the next super frame, entry slots of the radio communication apparatuses A, B, D, and G are seventh to ninth slots.

[0091]

Operations beacon communication at the time when the radio communication apparatus B withdraws from the radio network system after the radio communication apparatus G joins the radio network system will be explained. Note that it is judged that a radio communication apparatus is not in the neighborhood any more when the radio communication apparatus cannot receive beacons a fixed number of times continuously.

[0092]

First, when the radio communication apparatus B is not in the neighborhood any more, as shown in Fig. 9(a), the radio communication apparatuses A, D, and G do not receive beacons from the radio communication apparatus B. Thus, the radio communication apparatuses A, D, and G recognize all at once that a beacon formation has changed. Moreover, as shown in Fig. 9(b), the radio communication apparatuses C and F learn disappearance of the radio communication apparatus B in the next super frame. Since the second beacon slot of the radio communication apparatuses F and G is not filled by the radio communication apparatus E,

the radio communication apparatuses F and G judge that there is an empty slot among higher slots. Therefore, a value '3' is set in the movable counters 206 of the radio communication apparatuses F and G, respectively. However, only the radio communication apparatus G, which transmits a beacon in the lowest slot, has the right to move a slot. Thus, only the counter of the radio communication apparatus G is counted down (Fig. 9(c)).

[0093]

After the count down, as shown in Fig. 10(a), the radio communication apparatus G moves to the second slot. Consequently, the radio communication apparatuses A and D immediately detect the change of the beacon formation again and update the beacon periods from the first through the eighth slots. As shown in Fig. 10(b), the radio communication apparatuses C and F also detect movement of a slot of the radio communication apparatus G in the next super frame and update their beacon periods from the first to the eighth slots. Consequently, the radio communication apparatus F returns its movable counter to '0'.

[0094]

As shown in Fig. 10(c), the radio communication apparatus E receives the beacon slot length 305 from the radio communication apparatus C in the next super frame and updates the beacon period from the first through the eighth slots.

[0095]

As described above, in the radio communication network in this embodiment, a contraction operation for a beacon period is performed appropriately when a radio communication apparatus joins the radio

network system anew or disappears. Thus, the respective radio communication apparatuses can realize radio communication with high communication efficiency and less waste of consumed electricity.

[0096]

Note that two or more radio communication apparatuses may select the same entry slot simultaneously. The radio communication apparatuses that collided with each other then attempt to join the radio network system again. At this point, the conflicting radio communication apparatuses reduce the probability of the radio communication apparatuses conflicting again according to a "back off" algorithm.

[0097]

It will be explained how, when a moving radio communication apparatus is present in a beacon group, that radio communication apparatus communicates with the other radio communication apparatuses.

[0098]

Fig. 11 is an arrangement diagram of moving radio communication apparatuses.

[0099]

In this arrangement diagram, the radio communication apparatuses B to G (1102) are capable of communicating with one another. Moreover, the radio communication apparatuses B to G (1102) are also capable of communicating with a radio communication apparatus H (1103) in a communication area 1112. The radio communication apparatus H (1103) is also capable of communicating with a radio communication apparatus I (1104) in a communication area 1113. The radio communication apparatus

I (1104) is also capable of communicating with radio communication apparatuses J to L (1105), which are capable of communicating with one another, in a communication area 1114. In this way, the radio communication apparatuses B to L form one beacon group. A method of transmitting a beacon at the time when a radio communication apparatus A (1101) moves near the radio communication apparatuses B to L at appropriate speed will be explained below with reference to Figs. 12 to 15.

[0100]

First, when the radio communication apparatus A (1101) moves to a point 1121 in a communication area of the radio communication apparatuses B to G (1102), the radio communication apparatus A (1101) scans beacons around the point 1121 and transmits its beacon at one of the entry slots of a beacon period.

[0101]

Fig. 12(a) is a diagram showing the state of use of slots of the respective radio communication apparatus.

[0102]

In Fig. 12A, the radio communication apparatus A (1101) indicates that the radio communication apparatus A (1101) is transmitting its beacon at one of entry slots of the radio communication apparatus A (1101). The slots of radio communication apparatuses B to I indicate that the radio communication apparatuses B to I are transmitting beacons at the first to eighth slots, respectively. The slots of radio communication apparatuses J to L indicate that the radio communication apparatuses J to L are transmitting beacons in first to third slots, respectively.

[0103]

Since the radio communication apparatus A (1101) transmits the beacon in the third of the entry slots, the radio communication apparatus A performs counting of the movable counter 206 and commences a contraction operation. As a result, as shown in Fig. 12(b), the beacon slot of the radio communication apparatus A moves to the eighth slot and reduction of the beacon period is performed. At this point, the radio communication apparatus H learns the presence of the beacon of the radio communication apparatus A in the eighth slot according to beacon period occupancy information from the radio communication apparatuses B to G (1102). However, since the radio communication apparatus A is outside the communication area, communication of the radio communication apparatus H with the radio communication I is not hindered by the radio communication apparatus A.

[0104]

When the radio communication apparatus A moves to a point 1122 in the communication area of the radio communication apparatus H, beacons are sent to the radio communication apparatus H from the radio communication apparatus A and the radio communication apparatus I simultaneously in an eighth slot (1301). Fig. 13(a) shows a state of use of the beacon slot at this time.

[0105]

Since the radio communication apparatus H is near boundary of the communication area of the radio communication apparatus A, it is easier for the radio communication apparatus H to receive a beacon of the radio

communication apparatus I. Therefore, the radio communication apparatus H notifies the radio communication apparatus A, in the beacon period occupancy information 302, that the radio communication apparatus I is using the eighth slot. The radio communication apparatus A, which has received the notification, selects an entry slot in order to obtain a new beacon slot. As a result, as shown in Fig. 13B, the radio communication apparatus A acquires the ninth slot, which is one of entry slots, and transmits a beacon in the ninth slot.

[0106]

When the radio communication apparatus A moves to a point 1123 outside the communication areas of the radio communication apparatuses B to G, as shown in Fig. 14(a), the radio communication apparatuses B to G (1102) become incapable of transmitting and receiving information to and from the radio communication apparatus A directly.

[0107]

When the radio communication apparatus A moves to a point 1124 in a communication area of the radio communication apparatus I (1104), as shown in Fig. 14(b), the radio communication apparatus A transmits and receives beacon period occupancy information to and from radio communication apparatuses J to L (1105) via the radio communication apparatus I (1104). Consequently, it is recorded that the radio communication apparatus A is using the ninth slots of the radio communication apparatuses J to L (1105). In addition, it is recorded that the radio communication apparatuses J to L (1105) are using the first to the third slots of the radio communication apparatus A.

[0108]

When the radio communication apparatus A moves to a point 1125 outside a communication area of the radio communication apparatus H (1103), as shown in Fig. 15(a), the radio communication apparatus A becomes incapable of receiving beacon period occupancy information of the radio communication apparatuses B to G (1102) from the radio communication apparatus H. Therefore, the radio communication apparatus A judges that an empty area is formed in the high slot 1501, starts countdown of the movable counter, and moves a beacon to the fourth slot as shown in Fig. 15(b) after elapse of three cycles of super frames.

[0109]

In this way, even when a certain radio communication apparatus moves among other radio communication apparatuses, contraction operations for a beacon period are performed at appropriate times. Thus, even in such a state, it is possible to realize radio communication with high communication efficiency and less waste of consumed electricity.

[0110]

Note that, in this embodiment, the beacon sender information 301 and the beacon period occupancy information 302 of a beacon frame have respective counters, and counter values of the counters indicate whether a radio communication apparatus is at the stage when the transmission position of a beacon should be changed. However, a method of indicating the state of change of a beacon position is not limited to this counter, and it is also possible to use a flag. The radio communication apparatus sets a flag when the radio communication apparatus presently has a request for

changing its beacon slot position. The radio communication apparatus resets the flag when the radio communication apparatus judges that it is unnecessary to change a slot position or when a movable counter of the communication apparatus counts down and the beacon slot position is changed. The judgment on whether a counter value is 0 in the beacon slot position determination processing shown in Fig. 6 takes the form of judging whether this flag is set. This makes it possible to form a beacon frame necessary for processing for determining a beacon slot position with an amount of data smaller than that of the counter.

[Industrial Applicability]

[0111]

The invention is useful for a radio communication method and a radio communication apparatus which are used when ad hoc communication or the like is performed and when respective radio communication apparatuses in a radio network transmit beacons, is suitable for changing those beacons periods dynamically.

[Brief Description of the Drawings]

[0112]

[Fig. 1] An arrangement diagram of radio communication apparatuses forming a constitution of a radio network system according to a first embodiment of the invention.

[Fig. 2] A block diagram showing a constitution of a radio communication apparatus according to the first embodiment of the invention.

[Fig. 3] A diagram showing a constitution of a beacon frame

according to the first embodiment of the invention.

[Fig. 4] A diagram showing a format of a beacon slot state table according to the first embodiment of the invention.

[Fig. 5] A flow diagram showing a beacon period contraction operation according to the first embodiment of the invention.

[Fig. 6] A flow diagram showing beacon slot position determination processing according to the first embodiment of the invention.

[Fig. 7] (a) to (c) Diagrams each showing the slot state at the time when the radio communication apparatus joins a radio network according to the first embodiment of the invention.

[Fig. 8] (a) and (b) Diagrams each showing the slot state at the time when the radio communication apparatus moves a slot position after joining the radio network according to the first embodiment of the invention.

[Fig. 9] (a) to (c) Diagrams each showing the slot state at the time when the radio communication apparatus is not in the neighborhood any more according to the first embodiment of the invention.

[Fig. 10] (a) to (c) Diagrams each showing the slot state according to the first embodiment of the invention at the time when a contraction operation for a beacon period is completed after the radio communication apparatus is not in the neighborhood any more.

[Fig. 11] A diagram of the arrangement of moving radio communication apparatuses according to the first embodiment of the invention.

[Fig. 12] (a) and (b) Diagrams each showing a state of use of slots of the radio communication apparatus according to the first embodiment of the

invention.

[Fig. 13] (a) and (b) Diagrams showing a state of use of slots of the radio communication apparatus according to the first embodiment of the invention.

[Fig. 14] (a) and (b) Diagrams each showing a state of use of slots of the radio communication apparatus according to the first embodiment of the invention.

[Fig. 15] (a) and (b) Diagrams each showing a state of use of slots of the radio communication apparatus according to the first embodiment of the invention.

[Fig. 16] A diagram of the arrangement of radio communication apparatuses according to the first embodiment of the invention.

[Fig. 17] (a) and (b) Diagrams each showing a state of use of slots of the radio communication apparatus according to the first embodiment of the invention.

[Fig. 18] A diagram showing a conventional radio communication method.

[Description of Reference Numerals and Signs]

[0113]

101 to 107, 1101 to 1105, 1601 to 1604: Radio communication apparatuses

111 to 116, 1111 to 1115, 1611 to 1614: Communication areas

200: Antenna

201: Radio (L1) processing section

202: Frame judging section

203: Recording section

204: Upper layer processing section

205: Beacon slot position control section

206: Moving counter

207: Frame forming section

208: Beacon transmission command section

[Document Name] Abstract

[Abstract]

[Object] To provide a radio communication method in which communication efficiency is high and waste of power consumption is slight irrespective of the number of radio communication apparatuses participating in a radio network system.

[Solving Means] In a radio network system in which radio communication apparatuses transmit beacons using beacon periods so that the beacons do not conflict with one another, a beacon slot position control section 205 detects whether empty beacon slots are present in a beacon period. When an empty beacon slot is present before the period in which the radio communication apparatus transmits a beacon, a movable counter 206 starts counting a specified number of super frames until the beacon slot of the radio communication apparatus is moving to the empty beacon slot. When the count is completed, the radio communication apparatus transmits a beacon of the radio communication apparatus at the earlier empty beacon slot. Consequently, even if the number of radio communication apparatuses joining the radio network system fluctuates dynamically, the radio communication apparatus can perform radio communication with high efficiency and less waste of consumed electricity.

[Selected Drawing] Fig. 2